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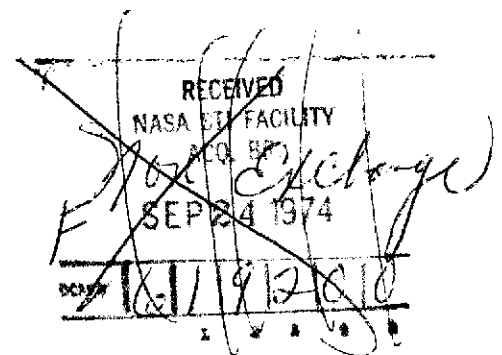
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AN EVALUATION OF THE UTILITY OF ERTS-1 DATA FOR MAPPING AND DEVELOPING NATURAL RESOURCES OF IRAN

TYPE II INTERIM REPORT FOR PERIOD JANUARY - JUNE 1973



PLAN AND BUDGET ORGANIZATION



Prepared for

GODDARD SPACE FLIGHT CENTER
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AND DEVELOPING NATURAL RESOURCES OF IRAN

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TABLE OF CONTENTS

Section I	Introduction	3
Section II	Geologic Applications	5
Section III	ERTS-1 Application to Hydrology and Water Management in Iran	22
Section IV	ERTS-1 Applications to Agriculture, Forest and Rangeland Management	28
Section V	ERTS-1 Application to Iranian Marine Resources	49
Section VI	Experiments in Urban Land-Use Analysis Using ERTS-1 Digital Tapes	55
Section VII	ERTS False Color Infrared Mosaic of Iran	63
Section VIII	Bibliography	67

LIST OF ILLUSTRATIONS

Figure II-1	Faults in Isfahan Province, central Iran
Figure II-2	Geologic mapping in the Tabas region, east central Iran
Figure II-3	Preliminary Tectonic Map of the Tabas Quadrangle, east central Iran, and Legend
Figure III-1	Map of Iran showing major drainage basins
Figure III-2	Lakes Observed in the Fars Region
Figure IV-1	ERTS-1 image 1294-06324 Shah Mazraeh Development Area test site
Figure IV-2A, B	Ground photographs of Agricultural Areas
Figure IV-3	Isfahan Agricultural Test Area ERTS Image
Figure IV-4	Ground photographs of Agricultural Test Area in the Vicinity of Isfahan
Figure IV-5	ERTS-1 frame 1059-06260-7 showing the Golestan Park range study area
Figure IV-6A, B	Ground photographs of Golestan Park range land test sites
Figure IV-7	Color composite of southeastern Caspian Sea ERTS-1 frame 1294-06339
Figure IV-8A, B	Ground photographs of Forest Test Site
Figure V-1	Coastal Wetlands and Sediment Currents southwest of Bandar Abbas
Figure V-2	Marshlands in the Arvand-Rud
Figure V-3	Northwestern part of Persian Gulf Showing Currents
Figure VI-1	Tehran frame from ERTS-1 Digital Tapes, Band 5
Figure VI-2	City of Tehran from ERTS-1 Digital Tapes, Band 5
Figure VI-3	City of Tehran from ERTS-1 Digital Tapes, Band 7
Figure VII-1	ERTS Color Mosaic of Iran

PREFACE

Summary of Project Status and Significant Results Obtained Using ERTS-1 Data

ERTS-1 data are now being applied by the Government of Iran to the following projects:

- Agriculture, forestry and range management
- Geologic and hydrologic mapping and interpretation
- Fisheries planning and inventory
- Land use analysis
- Photomap production

Significant results obtained in the January to June 1973 reporting period using ERTS-1 data include:

- The production of a color photomosaic of Iran. This project, now nearing completion, involves over 100 ERTS frames and is believed to be a unique accomplishment in the use of ERTS-1 imagery.
- Mapping of major tectonic, structural and stratigraphic geological features in Southern and Central Iran, including the discovery of numerous fault structures not shown on existing maps.
- Tectonic mapping and analysis of the Tabas Quadrangle in East-Central Iran.
- Mapping of lakes and reservoirs, including the identification of lakes that do not appear on current hydrological maps. These discoveries were confirmed by field trip analysis.
- Mapping of river channels and drainage patterns. Again, existing maps were found to be in error, in this case in the southeastern part of Iran.

- Use of ERTS-1 data in range surveys and agricultural surveys of Iran. A multi-stage sampling procedure using ERTS-1 data has been designed, test sites selected and field trips carried out.
- Fisheries nurseries, wetlands areas and coastal sedimentation patterns have been delineated and measured.
- Digital tapes have been processed and their application to urban land use demonstrated in the Tehran area.
- Iranian scientists have received intensive training in the United States on the interpretation and ground verification procedures used to analyze remotely sensed imagery.

The use of ERTS-1 and other satellite-derived data continues to occupy an increasing role in resource measurement and management in Iran, and major new activities are scheduled during the next reporting period.

SECTION 1

INTRODUCTION

Iran appears to be an almost ideal area in which to investigate the use of satellite-derived earth resources imagery. The country is largely cloud free for much of the year, and its size makes the synoptic view offered by ERTS the only practical approach for many resource measurement or management applications.

The preliminary study of the ERTS-1 imagery coverage of Iran commenced on October 26, 1972, (Ebtehadj, et al, 1973). All of the images were examined when received and a first photomosaic covering almost the entire country was prepared utilizing MSS Band 7 imagery. Images of selected areas were then studied in detail using a color additive viewer. At the same time, key personnel were trained in the USA and in Iran in the interpretation of ERTS-1 imagery and in ground verification procedures. A ground data collection program was set up in a number of selected test sites, to establish the relationship of satellite acquired data to ground features of interest. A variety of disciplines, including agriculture, forest and range resources, geology, water resources, and marine resources, were addressed.

Preliminary examination and evaluation of the ERTS imagery of Iran indicates the following:

- ERTS imagery is excellent for preparing reconnaissance geologic, tectonic, and mineral exploration maps. The imagery shows numerous previously unmapped faults and folds.
- The imagery will be of great value to hydrologic studies including exploration for ground water resources, estimating snow melt run off, general mapping of drainage basins, etc. The imagery has already proved its value by showing the

location of previously unknown fresh water lakes, and updating, refining and identifying errors on existing hydrologic maps.

- In many areas it is easier to identify and delineate the various categories of surficial deposits on the ERTS imagery than on the ground. This is of importance both to general geologic mapping and to ground water exploration.
- At a minimum the imagery will be useful for distinguishing broad vegetation categories (forest, range, and agriculture). Indeed, it is already being used on an operational basis for estimating amounts of forage available as part of an animal protein production improvement program.
- Indications are that ERTS data will be useful for crop identification and yield estimates and for a variety of forest management uses (monitoring illegal cutting, general inventory, burn damage assessments, etc.).
- The ERTS-1 digital tapes have excellent potential for use in land use studies, and show better radiometric range than the film products.
- An excellent color photomosaic can be created using the ERTS-1 imagery, and a 1:1,000,000 mosaic photomap that meets Natural Map Standards seems to be achievable.

These applications are each described in detail in Sections II-VIII.

SECTION II

GEOLOGIC APPLICATIONS

Introduction

The geologic portion of the Iran ERTS-1 project experiment is separated into two parts. Part 1 of the geologic experiment involved examining all of the imagery and the band 7 mosaic to obtain an idea of the general types of geologic information that could be extracted. The material in this section has been covered in our Type I reports, and is presented here in the form of a review. Part 2 of the experiment consisted of selecting a test area in order to evaluate the level of detail that can be extracted from ERTS for specific geologic purposes -- in this instance, tectonic mapping. The results of these two portions of the experiment are reported below under "General Geologic Results" and "Preliminary Geologic Map of the Tabas Quadrangle East-Central, Iran".

The geology and tectonics of Iran have been studied for the past 60 years by a number of investigators (see the explanation section, Geologic Map of Iran, by NIOC, 1959). Early geologic studies centered on the easily accessible north and south Iranian ranges and the oil rich Zagros Mountains. The Central Plateau, due to its extreme aridity and inaccessibility, remained untouched. Boeckh, et al. (1929) summarized the regional structural elements of the country from south to north as:

- ° Stable foreland - the Saudi Arabian Peninsula
- ° Major geosyncline - coincides with the Zagros Mountains
- ° Zones of nappes and thrust faulting - the Zagros thrust belt
- ° "Central Stable Platform" - underlying the Iranian Plateau, and
- ° Major geosyncline - coincides with the Elburz Mountains.

It was not until 1950 that systematic studies were undertaken in central Iran by geologists of the National Iranian Oil Company (NIOC).

The most important results of these investigations were summarized on the Geological Map of Iran (NIOC, 1959).

A major contribution in this subject was made by Stocklin (1968) who showed that highly deformed cores of Jurassic and Cretaceous mountains exist in the central plateau of Iran. Therefore, he discarded the concept of a "central stable platform." From 1967 to the present, additional data was collected by the Iranian Geologic Survey (IGS) in order to understand better the tectonic configuration of the country and to prepare a tectonic map.

Part 1: General Geologic Results (See Type I report for details)

The photomosaic of ERTS-1 images (band 7) was compared with the 1:2,500,000 Geological Map of Iran, and the 1:1,000,000 Geologic Map of S. W. Iran, compiled by the Iranian Oil Operating Companies. Particular attention was given to the tectonics and the lithologic characteristics of different test sites. A preliminary study was also carried out on surficial deposits, especially alluvial fan surfaces and deposits in playas.

Major Geologic Features

The following major tectonic, structural and stratigraphic features are readily visible on the mosaic composed of ERTS band 7 imagery:

- A major fault, several hundred kilometers in length, and more or less parallel to the Zagros Thrust Fault was identified in the southern portion of the country. This fault was not previously recorded, and thus does not appear on the geological maps (Figure II-1).

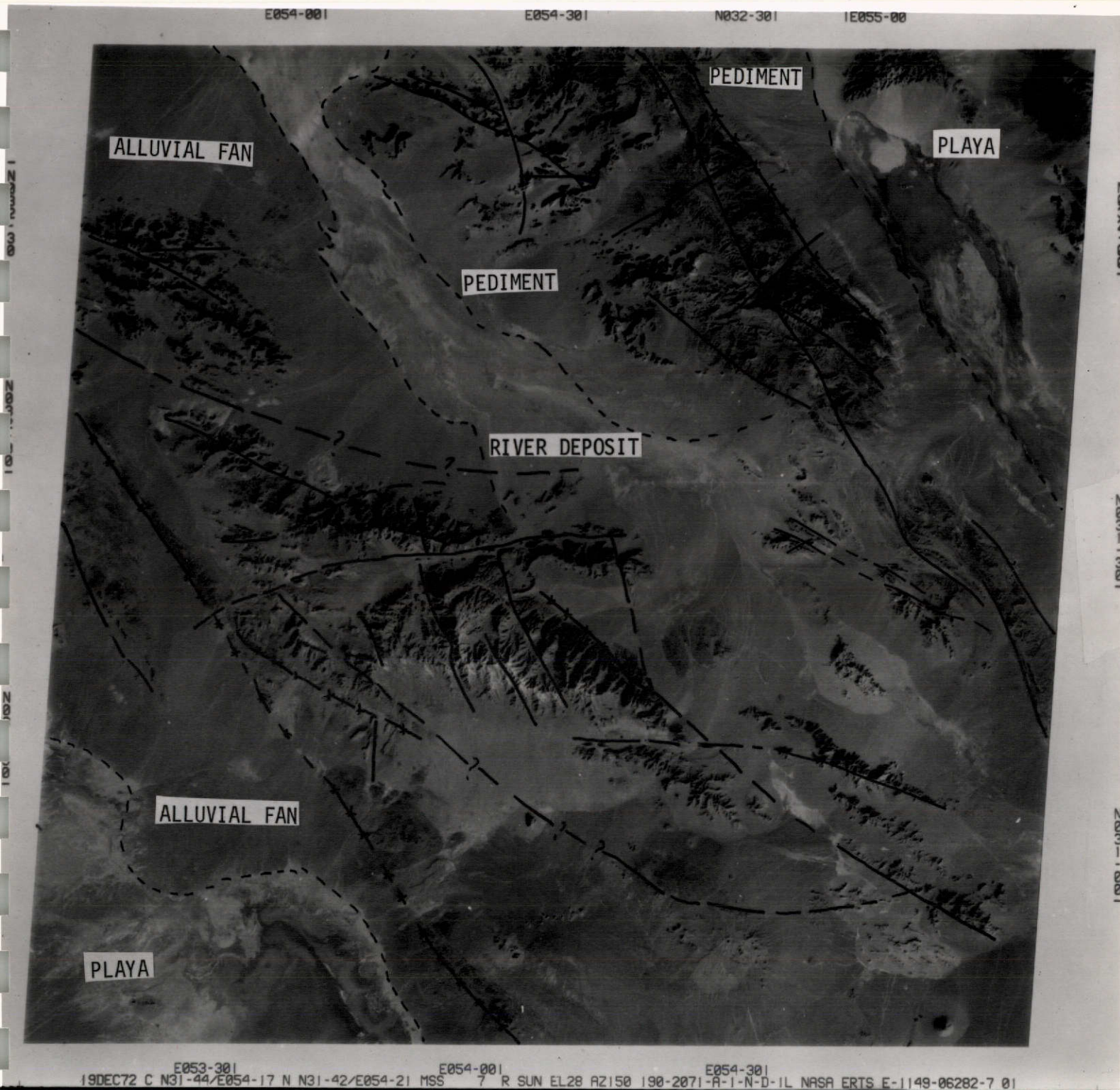


FIGURE II-1 FAULTS IN ISFAHAN PROVINCE, CENTRAL IRAN

ERTS-1 Image 1149-0628, MSS band 7, 19 December 1972

LEGEND

0 — 10km
scale

Previously observed faults — x — x —
Newly observed faults — — — — —
Boundaries between different Regolith
Deposits - - - - -

- Preliminary study of the ERTS-1 imagery of the southeast part of Iran established the presence of many more faults than appear on our geological maps.
- Numerous anticlines, synclines, and salt domes which characterize the SE part of the Zagros range, are clearly visible on the image taken of the Bandar Lengeh area, and a regional map of the area was prepared to complement existing large scale maps.
- A series of fairly large faults with a northwest trend were identified on the ERTS-1 images taken of the Isfahan area. These faults do not appear on any of our geological maps. Another series of west trending faults truncates this series of faults and a portion of the Zagros Thrust Belt (Figure II-1). The existence of these fault systems was verified in a geologic field trip to the test site area.

Surficial Deposits

The areal extent, and the boundary between alluvial fans and other types of unconsolidated sediments are easily observable on the ERTS-1 images. In many instances these boundaries are more visible on ERTS imagery than on the ground. Since most wells or ghanats* in Iran are drilled or dug in alluvial deposits, the distribution and differentiation of these deposits, is of great significance for hydrogeological investigations, and artificial recharge.

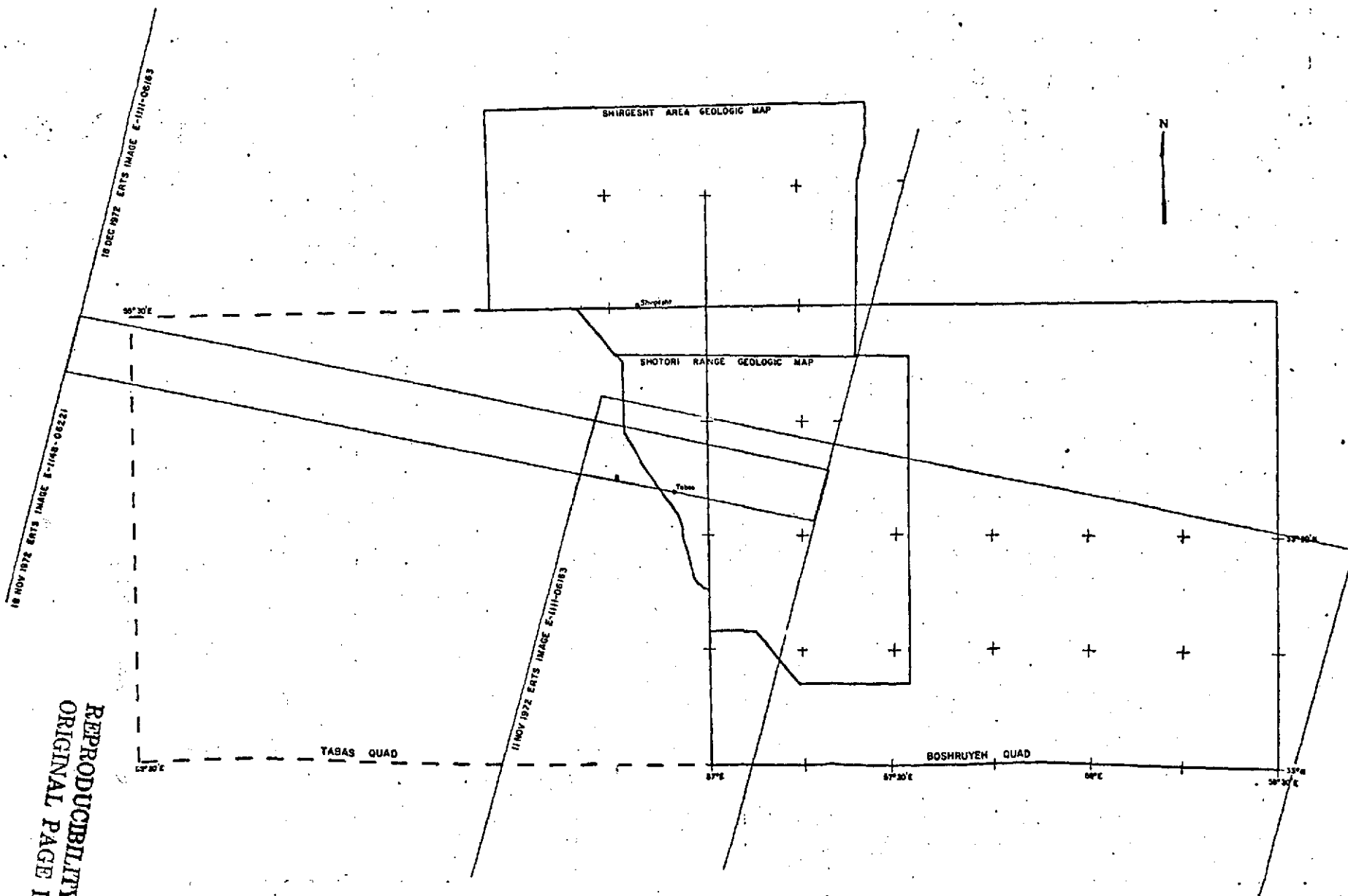
A relatively detailed study of the unconsolidated sediments was carried out on the imagery taken of Isfahan (Figure II-1). As a

* Ghanat is a horizontal interceptor to the ground water table, which is linked through a series of interconnected wells. The flow from the intercepted water table is thus directed through the underground channel to the population center (Wulff, 1968).

result, different types of recent unconsolidated sediments, i.e., alluvial fans, lake evaporite deposits, river deposits, and talus were differentiated based on tonal differences. Areas covered by the weathered and eroded by-products of nearby outcropping igneous, metamorphic and sedimentary source rocks are characterized by dark-gray to black shades, whereas the by-products of weathering and erosion of reworked surficial material appear as gray patches. Finally, sediments (mostly evaporites) present in playas and river channels, are visible as white patches. Differentiation and mapping of different surficial deposits are of economic importance for locating potential water resources and arable lands.

Part 2: Preliminary Tectonic Map of the Tabas Quadrangle, East-Central Iran

Background: The second objective of the geologic portion of this experiment is to investigate the level of detail of geologic and tectonic data that may be obtained from ERTS imagery in the context of Iran. This section of the report deals with a test of ERTS imagery for tectonic mapping of the Tabas Quadrangle in east-central Iran. This quadrangle was chosen as a test site because it has good geologic maps bordering it on two sides (see Figure II-2): the geologic map of the Shirgesht Area (Ruttner, et al, 1968) to the northeast and the geologic maps of the Shotori Range (Stocklin, et al, 1965) and the Boshruyeh Quadrangle (Eftekhar-nezhad, et al, 1971) to the east. The Tabas Quadrangle is also, in part, included in a 1:5,000,000 scale tectonic map included in Stocklin (1968). In addition, we had access to excellent 1:500,000 scale false color ERTS images of this area.



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FIGURE II-2 Geologic Mapping in the Tabas Region, East-Central Iran.
The limits of existing geologic maps adjacent to the Tabas
Quadrangle are outlined.

In the ERTS imagery, the most readily available information is structural information; interpretation for lithological data, except for the most generalized rock type categories, requires considerable subjective judgment and field work. Thus, in this present experiment we will limit our objective to the production of a tectonic map (which emphasizes structural features) for the guidance of exploration for mineral resources and not attempt a geologic map which would require detailed lithologic information. This initial attempt involved interpretation at a scale of 1:500,000 for a map to be reproduced at 1:1,000,000 scale.

The scale limitation is such that we perhaps cannot expect to recognize directly intrusions the size of a typical porphyry copper deposit, but we might expect to see the structural intersections that may control their location. The petroleum exploration geologist should be able to use the map to guide his thinking as to the structural grain of the region. He will be able to directly recognize some of the larger anticlinal features. The map will also be useful for ground water exploration.

To our knowledge, this is the first time ERTS imagery has been used on an operational basis for producing a tectonic map of an area. The results of this effort are so encouraging that we hope to map all of Iran eventually using the techniques we developed during this experiment.

Interpretation of the Tabas Quadrangle

The critical factor for tectonic interpretation is the boundaries between tectonic units must be based upon practical objective criteria that are observable in the imagery. Moreover, appearance of these boundaries may vary with the crustal level that is exposed and the thickness and character of any post-orogenic supracrustal cover.

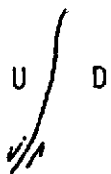




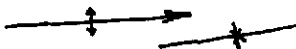



Based on examination of the ERTS imagery (Frames 1148-06215 and 06221), and review of available literature, the Tabas Quadrangle consists of five major morphological units. This interpretation was performed on 1:500,000 scale color composites (bands 4,5, and 7) of the ERTS imagery and photographically reduced to a scale of 1:1,000,000 (Figure 11-3). These units are:

1. The Shotori range in the northeast which was well mapped at a scale of 1:100,000 by Stocklin, et al, (1965). This range consists of a folded and strongly faulted block of Permian and Mesozoic sedimentary rocks bordered by a Paleogene volcanic sequence on the east. The range is a horst bounded on the east and west by grabens.
2. The sediments derived from the Shotori and Pirhajat ranges. These are also, in part, mapped by Stocklin, et al, (1965) and by Ruttner, et al, (1968). This is a graben in which the exposures are mainly gently folded Neogene continental red beds.
3. The Pirhajat ranges of which the northern parts, north of the Tabas Quadrangle, were well mapped by Ruttner, et al, (1968). This, on the basis of Ruttner's work and our interpretation, is essentially an anticlinal mountain range of folded and faulted Mesozoic marine sediments draped over a core of Paleozoic rocks. The Mesozoic rocks, which outcrop, are younger in the southeast and are progressively older to the northwest in the range, implying greater uplift by Quaternary block faulting in the northwest.

FIGURE II-3, PART 1
LEGEND FOR PRELIMINARY TECTONIC MAP OF
THE TABAS QUADRANGLE

<u>Symbol</u>	<u>Tectonic Unit</u>	<u>Description</u>
S	Undeformed quaternary surficial deposits	
S _a		Alluvium
S _f		Alluvial fans
S _p		Pediment surface
S _e		Eolian deposits
S _s		Playa deposits (salt and clastics)
N	Gently folded and block faulted Neogene continental deposits	This is a gently deformed continental red bed sequence that represents the continuing upper Alpine deformation. Fold axis orientations are varied and related to adjacent block faulting.
L	Long linear folds of well bedded Eocene marine sediments	The angular discordance between this unit and the next one is small and these sediments have participated in the same cycle of long linear folds with NS axes. This represents the culmination of the middle Alpine stage deformation in this area.
M _u	Long linear folds of well bedded Cretaceous marine sediments	The folding is concordant with the above unit but the angular discordance in bedding suggests tilting and erosion (perhaps emergence) during Paleocene. Fold axes are NS.
M _m	Strongly faulted, well bedded upper Jurassic evaporites and marine sediments	The abrupt difference in structural style indicates that the early Alpine stage in this part of Iran was responsible for intense brittle deformation (faulting) and jointing rather than the simple compressional folding of the later Alpine stages. However, long NS strike ridges are probably the result of the later Alpine stages of deformation. Fold axes are poorly defined, probably because of the development of axial faulting.

<u>Symbol</u>	<u>Tectonic Unit</u>	<u>Description</u>
M _L	Upper Triassic continental deposits which form the discordant cores of anticlinal features in the M _m sediments	The intensity of brittle deformation of initially poorly bedded continental sediments makes interpretation difficult in the small areas available for interpretation, but the outcrop location suggests that the Pirhajat Range is essentially anticlinal and that intense deformation occurred between the the Upper Triassic and the upper Jurassic. The anticlinal aspect of the range is a late Alpine stage feature.
P(?)	Older more highly metamorphosed rocks	These rocks do not have contacts in common with any of the deformed rocks listed above in this quadrangle, therefore, we will have to await the interpretation of adjacent quadrangles before commenting on their relative tectonic history.
I	One outcrop of massive unbedded rock occurs on the western edge of the quad	The geologic map of Iran (NIOC, 1959) indicates that the intrusion came into the P(?) above but further interpretation is needed on the quadrangle to the west.

	Faults
	. Normal
	. Transcurrent
	Contacts of tectonic units
	Traces of bedding
	Fold axes
	Intra unit contacts
	Generalized strike and dip of bedding
	Prevailing wind direction from June interpretation



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FIGURE 11-3 PART 2 Tectonic Map of the Tabas Quadrangle

4. The eastern edge of the Great Kavir depression, including the western sediment of the Pirhajat range. The ERTS imagery interpretation suggests that this is a complex of grabens with isolated outcrops of gently folded continental red beds, rather similar to unit 2 above except for the enormous extent of this unit; the western boundary was not visible on our imagery.
5. Isolated small ranges of pre-Mesozoic metamorphic rocks in the southwestern portion of the quadrangle. These rocks are identified on the geologic map of Iran (NIOC, 1959) as metamorphic rocks of undetermined age. The ERTS correlation suggests that they are, at least similar to the Paleozoic core of the Pirhajat range.

The Tabas Quadrangle has been divided into eight Tectonic units on the basis of the interpretation of ERTS. The ERTS imagery appears to be excellent for this purpose. These units and their basis for identification are discussed below.

The youngest unit separated on the tectonic map is the essentially undeformed Quaternary surficial deposits. These deposits are unconsolidated and would only be expected to show deformation in exceptional circumstances such as the offsetting of salt rinds in the Great Kavir. West of the Pirhajat range large areas of dunes cover all outcrops and structures and completely mask the bedrock geology. The wind driving these dunes is controlled by local mountain locations and where interpretable, wind directions have been noted. Alluvial fans are noted as possible sources of stored ground water. This tectonic unit is important to exploration as it covers other units of interest and for the ground water stored in it.

The next older unit consists of a gently folded continental red bed unit which is symbolized on the map by an "N" because it is identified as Neogene by Stocklin et al (1965). The red beds are probably in part transitional into the overlying surficial deposits as the surficial deposits represent a continuation into the present of the Neogene depositional environment but in the Tabas Quadrangle interpretation the Neogene was indicated only where the bedding has a definite dip with respect to the present surface. The lower contact of the Neogene red bed sequence is a major angular unconformity in the Tabas Quadrangle as the next older unit is concentrically folded and strongly faulted Eocene marine sediments. The change in tectonic style between the two units is striking because the Eocene folding exhibits strongly parallel axial planes and extremely uniform spacing of fold axes in very well bedded marine sediments. The superjacent Neogene on the other hand is a poorly bedded, tectonically disrupted sequence with broad domal folds whose axes are more nearly related to local block faults. The two units are in fault contact everywhere observed in the Tabas Quadrangle. Thus, contact relations are somewhat obscured. In adjacent areas (Stocklin, et al, 1965) Paleogene volcanics and volcanic sediments separate the two units but the volcanics apparently do not occur in this quadrangle. According to Stocklin (1968), the Neogene deformation is late upper-Alpine stage deformation.

The Paleogene volcanism is important in porphyry copper exploration because in adjacent areas the igneous activity seems to be closely related in time and space to emplacement of the porphyry intrusions.

The next older unit outcropping in the Tabas Quadrangle, the Eocene marine sediments, have been described above. This unit outcrops in a very small area on the southern border of the quadrangle in the southeast part of the Pirhajat range. It is much more widespread in the quadrangle to the south. It rests with small angular discordance on a Cretaceous fold belt and for the purposes of this presentation could well have been represented as a subunit of the underlying Cretaceous because of the great similarity of tectonic style. The decision to depict this as a separate unit is based upon the need of porphyry copper exploration geologists to have all the details of tectonic events at about this period in the tectonic history.

The angular discordance between the Eocene (L) and the Cretaceous marine sediments (Mu) is small but well defined just south of the Tabas Quadrangle, but the tectonic style is very similar and fold trends and axes in one unit often continue into the next unit. The folds indicate post-Eocene pre-Miocene east-west compression followed by left lateral faulting along an essentially north-south system of faults, indicating a shift of the primary compression direction from west to northwest. These same faults were reactivated in the Neogene as normal faults in which appears to be a basin and range type crustal extension.

The next oldest tectonic unit is the middle Mesozoic (Mm) marine sedimentary, mainly limestone, sequence whose outcrop and tectonic style indicate that they had been deformed and welded into a compact unit before the Cretaceous deposition and deformation. Few signs of the east-west compression that produced the Cretaceous folding are apparent in the rocks because ~~of~~ the post-Jurassic pre-Cretaceous Lower Alpine phase of deformation had already welded these rocks into

a more or less uniform mass. This deformation does not appear to have been accompanied by igneous activity in the Tabas Quadrangle or in the adjacent well mapped areas. These rocks form a part of the basement for porphyry copper exploration. Structural trends, fold axes, bedding traces and faults, are more varied than in the Cretaceous rocks, but the north trend is still dominant and bedding is not so well defined at ERTS scale. The contact between this unit and the Cretaceous above is faulted, but where interpretable, it is a strong angular unconformity.

The oldest tectonic unit present on the Tabas Quadrangle is mapped as undated "metamorphics" (P(?)) on the Geologic Map of Iran (NIOC, 1959) and as "Ancient Cores" (M1) by Stocklin (1968). It includes, in this area, the low grade metamorphic equivalent of the Paleozoic sedimentary rocks of the Shirgesht area to the north (Ruttner, et al, 1968). In the Tabas Quadrangle these rocks form the cores of antiformal features and occur as isolated mountain ranges in the southwestern part of the quadrangle. In both areas they show major structural discordance with the younger rocks but none of the areas are large enough at the interpretation scale to allow interpretation of their internal structure and tectonic style. The older rocks form a northeast trending string of structural highs along the east edge of the Dasht-i-Kavir making the westernmost ranges of the Pirhajat ranges anticlinal. This string of highs is at a 30° angle with the younger grain and probably represents the grain of earlier Alpine phase deformation. These rocks are also basement for porphyry copper deposits.

The results of our attempt to produce a tectonic map of the Tabas Quadrangle are portrayed in Figure II-3. This figure consists

of a legend and a delineated image and demonstrates the level of tectonic detail it is possible to extract from ERTS imagery at a scale of 1:1,000,000.

Program for the Next Reporting Period

During the next reporting period we anticipate further field checking of the inferences drawn from the preliminary examination of the ERTS imagery and of the tectonic mapping of the Tabas Quadrangle. We plan to begin a systematic detailed examination and interpretation of the ERTS imagery using the color composite mosaics as a basis for compiling our observations. We will continue our investigation of ways to integrate ERTS imagery into current mineral exploration programs.

Conclusions

From the generalized examination of the band 7 mosaic of all Iran, we conclude:

- ERTS imagery will be exceedingly valuable for recognizing and mapping many types of geologic features particularly faults and folds. This will be of great value for mineral and petroleum exploration and the location and identification of geologic hazards such as active faults.
- In many areas, ERTS imagery is excellent - often better than traditional, ground methods - for mapping boundaries between different types of surficial deposits. These boundaries are important for ground water exploration.

We may conclude from the test interpretation of the Tabas Quadrangle that ERTS image interpretation provides a uniquely valuable basis for preparation of tectonic maps. A tectonic unit defined in

terms of characteristics interpretable from ERTS imagery proves to be an invaluable correlation tool for analysis of large areas. We must note that we feel that Iran is well suited to this type of interpretation based on ERTS (or other space acquired imagery) because of generally clear atmospheric conditions and the absence of masking vegetation. This approach may not be as effective in regions of the world that do not have these characteristics.

SECTION III
ERTS-1 APPLICATIONS TO HYDROLOGY AND WATER
MANAGEMENT IN IRAN

Introduction 1/

The average amount of precipitation (rain and snow) for Iran does not exceed 28 centimeters per year. This is due to geographic location and orographic effect of mountains surrounding the country. A water balance study, using five years of continuous hydrologic data (1966-1971) collected from all existing precipitation and stream gauging stations shows that the average yearly volume of precipitation for the entire country is about 368 billion cubic meters (BCm), and the amount of stream runoff is approximately 78 BCm annually. Most of the remaining amount of precipitation is consumed by evapotranspiration, due to the extreme aridity of the country. There is also a substantial amount of infiltration (Akhavi, et al, 1973).

The water balance study also indicates that the distribution of rainfall is not uniform in Iran. Basin Nos. 1, 2-1 and 3, which cover only 25 percent of the country, receive about 50 percent of the total precipitation. The remaining amount of rainfall is distributed over the other hydrologic basins which cover 75 percent of the country (Figure III-1).

Due to the scarcity and non-uniform distribution of snow and rainfall, the study and management of water resources are of prime importance to Iran. For this reason, new sources of obtaining supplementary information (such as satellite acquired data) are very important.

1/ This section is substantially a review of the material presented in our Type I report, in accordance with reporting requirements under Section 1.2.2 of G.S.F.C. Specifications.

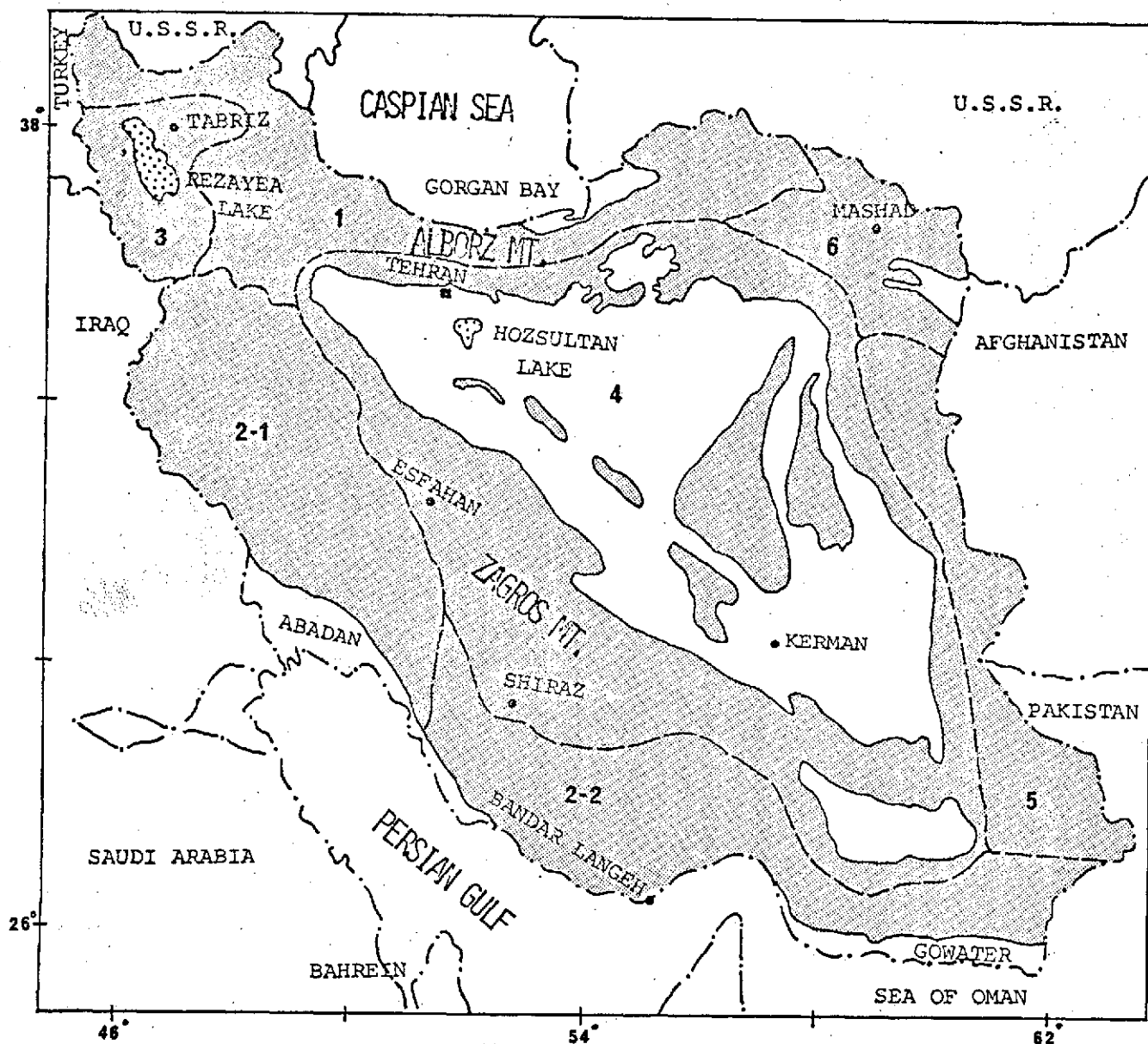


FIGURE III-1

MAP OF PRINCIPAL DRAINAGE

BASINS OF IRAN

(Numbers refer to drainage basins mentioned in the text).



--- WATERSHED BOUNDARY



MOUNTAINS



LAKES

0 174 mi

Degree Coordinates and Scale are Approximate.

Results

In the present investigation the ERTS-1 images were used to collect supplementary water resources data in selected test sites - the Fars Province (southern Iran), the southeast corner of the Caspian Sea, the Hozsultan Lake (south of Tehran) and the northwest region of the Persian Gulf.

The significant results may be summarized as follows:

Lakes - The nature, distribution and location of water bodies as observed on the photomosaic of the ERTS-1 images were compared with the 1971 Hydrological Map of Iran. Three new lakes were identified on the ERTS-1 imagery coverage of the Fars Province (Figure III-2) which do not appear on hydrological maps of this region. These lakes are:

1. The Dariush Kabir dam and reservoir built on the Kor River in 1972.
2. A small lake in the Sivand River basin.
3. A small lake north of the Parishan Lake in the Kazeroon area.

Lake 1 was not on the hydrological Map of Iran because it was published in 1971, and at that time construction of the Dariush Kabir dam, and its associated reservoir was not yet completed. The absence of Lake 2 on the 1971 map and its presence in the 1972 imagery probably are due to its formation in the 1971-72 season due to abnormally greater precipitation. This discovery illustrates emphatically the importance of cyclic repeat coverage of dynamic hydrologic features. Field investigation in the Kazeroon area proved that small lakes (Lake 3) observed in images are formed by ground water discharge from a karst limestone into a shallow depression. This is an exceedingly valuable discovery.

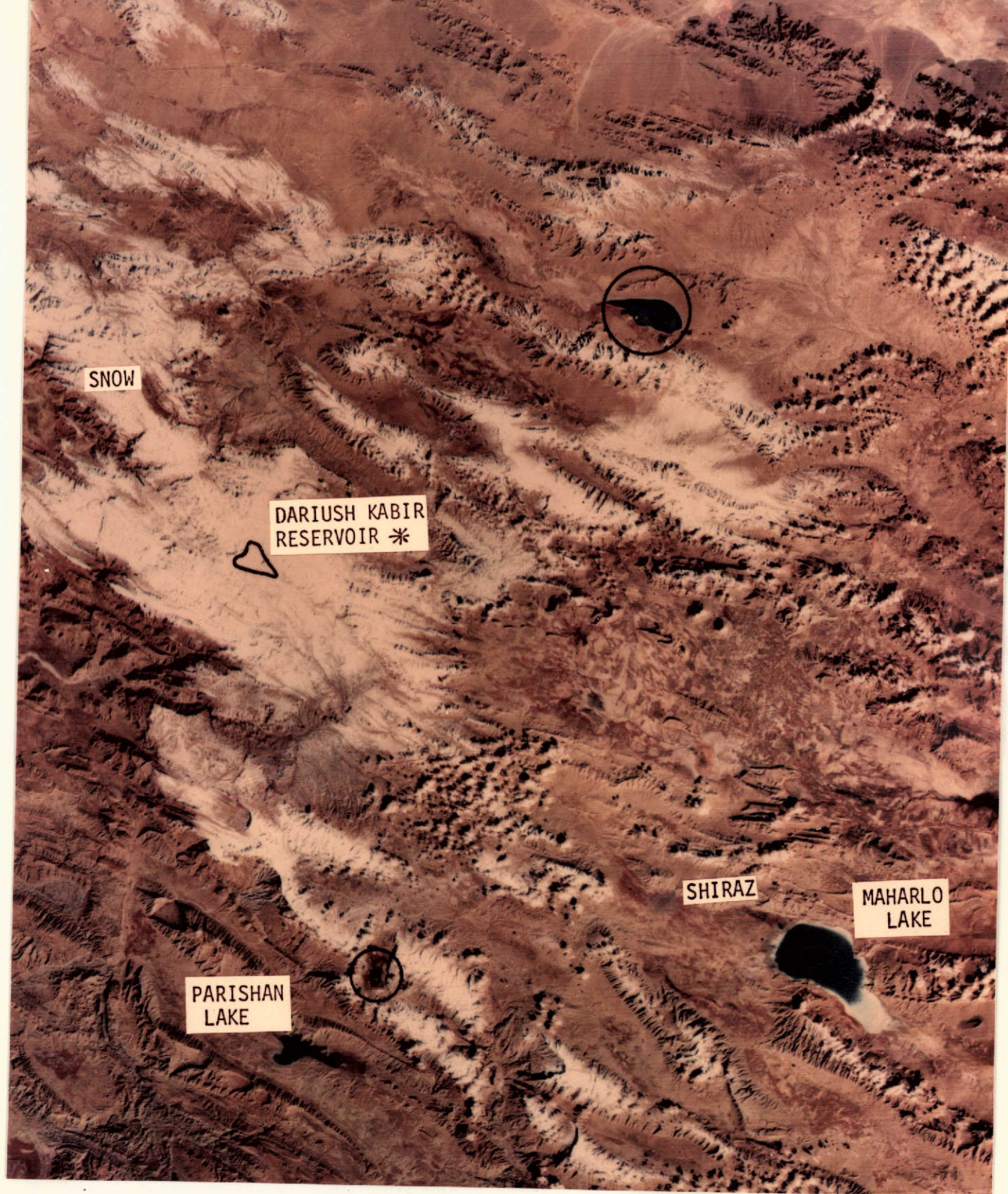


FIGURE III-2 LAKES OBSERVED IN THE FARS REGION

ERTS-1 Images 1150-06342 and 1150-06345,
MSS band 7, 20 December 1972



LEGEND



Newly Observed Lakes
Dariussh Kabir Reservoir was observed in
previous images. In this imagery it is
obscured by snow.

While using a color additive viewer to study the ERTS-1 images taken of the Fars Province, it was noticed that some water bodies exhibit tonal differences. This phenomenon presumably is due to some combination of the following factors:

- Depth of water
- Chemical composition of water
- Suspended sediment
- Presence of organic material, i.e. algal growth.

The cause of the tonal differences is probably different for different lakes and needs to be investigated on the ground.

The image of Hozsultan salt lake taken by ERTS-1 on September 4, 1972, shows a body of water about 18 Km² in size, present in the western part of this salt lake basin. But on the series of images taken 18 days later the areal extent of this body of water had decreased to the point of being barely discernible. This phenomenon is probably due to extensive evaporation and very little surface or subsurface replenishment. The changes observed indicate the value of ERTS for monitoring dynamic phenomena.

Rivers - River channels and their drainage pattern are easily observed on the ERTS-1 imagery. Thus, after ascertaining the area of each watershed, with future repetitive coverage, it may be possible to initiate seasonal yield forecasting for particular streams, taking into account snow coverage and nature of each particular stream.

While examining the imagery of Gowater Bay (near the Pakistan border) in the extreme southeastern region of Iran, it was observed that four south flowing streams could be seen discharging into Gowater Bay. The Hydrological Map of Iran shows only three streams. This observation demonstrates the value of the ERTS imagery for updating and correcting drainage maps.

Program for the Next Reporting Period

We anticipate undertaking a systematic comparison of the ERTS-1 imagery and the Hydrologic Map of Iran in an effort to update this map. We will field check and verify the possibility of differentiating and mapping the types of surficial deposits in various parts of Iran, to develop further the interpretation of ERTS imagery as a tool for ground water exploration. The causes of the tonal differences observed in the various lakes will be investigated, to see if the imagery can be used as a tool for monitoring water quality and/or depth in remote areas of the country.

Conclusions

The experience of Iran to date in applying interpretation of ERTS imagery to hydrologic problems indicate that:

1. The imagery is exceedingly valuable for mapping surficial deposits of interest in groundwater exploration.
2. The imagery can be used to update existing hydrologic maps and even locate previously unknown rivers and lakes.
3. It may be possible to use repetitive ERTS coverage to monitor snow cover, water depth and water quality.

All of these applications are of great potential value to the Government of Iran.

SECTION IV

ERTS-1 APPLICATIONS TO AGRICULTURE, FOREST, AND RANGELAND MANAGEMENT

Introduction

The agriculture, forest, and range resources of Iran are presently the subjects of large scale, intensive development programs. Several studies have been undertaken in agriculture in recent years, particularly in the Caspian Sea area, to determine the best strategy for allocating land use between agricultural crops and pasture grasses. The determination of an optimum balance of land use between crops and pasture is particularly pressing now because of the urgent need to increase animal protein production throughout Iran. One important way of achieving increased animal production is by pasturing more animals, from time to time, that normally feed on natural range lands so that these lands can at least partially recover from years of overgrazing.

A range survey of Iran, which uses ERTS-1 data in a multistage sample design, has been undertaken to determine the current status of the range resources and to locate areas of the highest productive potential. The use of ERTS-1 imagery to help monitor the status and distribution of range grasses could prove to be of tremendous benefit in a cattle expansion program. This survey is described in more detail later in this report.

The Ministry of Agriculture is engaged also in studies to improve food production through irrigation, fertilization, and genetic improvement of planting stock. In order to monitor the current crop production, the Ministry periodically gathers statistics concerning the amount of distribution of yields.

These are tremendously difficult tasks. Currently, the Ministry depends heavily on questionnaires and reports sent in by farmers. Because of the inaccessibility of many villages, the gathering of the

information is very difficult. Furthermore, many farmers do not respond, and different interpretations of the questions are not uncommon. Also, different agricultural practices prevail in various parts of the country. Altogether, these conditions make it difficult to obtain consistent data over the entire country in any one period of time. The introduction of ERTS technology, therefore, could greatly facilitate the planning and execution of crop surveys in relatively short periods of time. Because of the divergence in land form and climate varying, strategies are being examined. In the Caspian Sea area, the farm lands are more or less contiguous with some intermingling of high quality grazing land. This situation calls for one class of possible sample designs. On the other hand, the remainder of Iran has a much dryer climate. Hence, the agricultural areas are relatively small and widely scattered. The latter situation calls for a different sampling approach than the former for optimum results. In both instances, however, ERTS-1 imagery provides an excellent medium for locating all the crop areas in the population and setting up the sampling frame for crop census activity.

In the current ERTS-1 investigation in Agriculture, four major objectives are being sought. These are:

1. The development of methods to inventory farming and grazing lands
2. The identification of new lands suitable for farming
3. A classification map showing land use, and
4. The development of techniques to discriminate between agriculture and range areas and to measure change.

Forest resources of Iran are restricted mainly to the north slopes of the Elburz Mountains which ring the agriculture region south of the Caspian Sea. While restricted in area, the forests do contain significant amounts of beech, maple, oak and pine in addition to several minor

species. There are also some oak forests in the western part of the country, but these do not have the productive capacity of the Caspian Sea forests because of the much more arid climate.

The main problems in forestry that can be addressed by means of ERTS-1 technology deal with obtaining an adequate inventory of the forest resources and in monitoring changes that are taking place as a result of logging, burning or grazing. Historically, the forests have been heavily used for timber, firewood, charcoal and grazing. However, much of this usage has been sporadic in nature depending on the needs of local residents. Therefore, there is no consistent record of the status of the present forest resources even though they are now protected from indiscriminate use. Since some of the prime forest areas are now being brought under more intensive management and utilization, (i.e. the Neka Zalem Rud Project) the need for more current information concerning the quantity, quality and location of forest resources will steadily increase. The introduction of ERTS technology into Iran's forest inventory and management program would help accelerate the achievement of these goals.

The main forestry objectives of the present ERTS-1 study are to:

1. Explore the feasibility of classifying forest types on the imagery for use in inventory and management programs,
2. Plan the location and development of access roads and fire breaks on a broad scale, and
3. Determine the feasibility of monitoring changes in forests that occur as a result of planned harvesting and sporadic cutting by local residents.

Results to Date

The progress achieved toward satisfying the objectives specified above in agriculture, range and forestry, during the first six months

of this effort has been:

1. Training in the handling and use of ERTS data
2. Familiarization with the interpretation equipments available
3. The exact identification of test areas, their delineation on ERTS imagery, and the gathering of ground truth information.
4. The implementation of a range resources inventory using ERTS-1 data in the first stage of a multistage sampling design.

A more detailed discussion of the above results follows below:

Training and Familiarization

A course in remote sensing techniques and the application of ERTS imagery to resource surveys and management problems was conducted by Earth Satellite Corporation (EarthSat) and attended by ten key scientists and administrators from the Plan Organization and other resource ministries of Iran. During this program, ERTS images of Iran were studied in conjunction with the study of images of similar areas in the Southwestern United States. Farm, range, and forest areas were studied to determine the appearance of different agriculture and forest types on ERTS images. Image enhancement devices, such as the I²S Digicol were employed to determine the improvement that can be gained in identifying these kinds of resources compared to the black and white material.

Field trips were undertaken throughout California and Arizona for the purpose of comparing the appearance of the different kinds of vegetation on the ground with their signatures on the ERTS data. During these trips, different kinds of crop and forest types were visited and compared with the imagery. In addition, several visits were made to range areas in the American Southwest.

Establishment of Test Areas in Iran

After the study team returned to Iran, ground visits were made to several areas that resulted in the establishment of four test sites; two in agriculture, one in forestry, and one in range.

A. Agricultural Test Sites

The Shah Mazraeh Development Area

One site chosen to study the signatures of key agricultural crops on ERTS images over time is the Shah Mazraeh Development area near Gorgan, in the Caspian Sea area. This agricultural development area was established about ten years ago to study farming methods and crop rotation plans in this prime agricultural region of Iran. The main crop types currently being grown here are cotton, wheat, barley (irrigated and dry land), and pasture grasses with smaller amounts of corn, sunflowers, and orchard crops.

During the field visit to this area in April 1973, an identification was made of the crop that was grown on each field in 1972 as well as the crop being grown in 1973. These identifications were indicated on large scale maps which show clearly the locations of the field boundaries. Then an overlay was prepared at a scale of 1/250,000 to match an enlargement of ERTS frame number 1294-06324, 13 May 1973 (Figure IV-1). While this scene is partially obscured by clouds, there is enough of the area visible to allow an investigation into various multispectral techniques for discriminating among the crop types. Figure IV-2A, shows a barley field in the center of the test site. This field has visible color values very similar to nearby pasture grasses (Figure IV-2B). To distinguish between these two kinds of

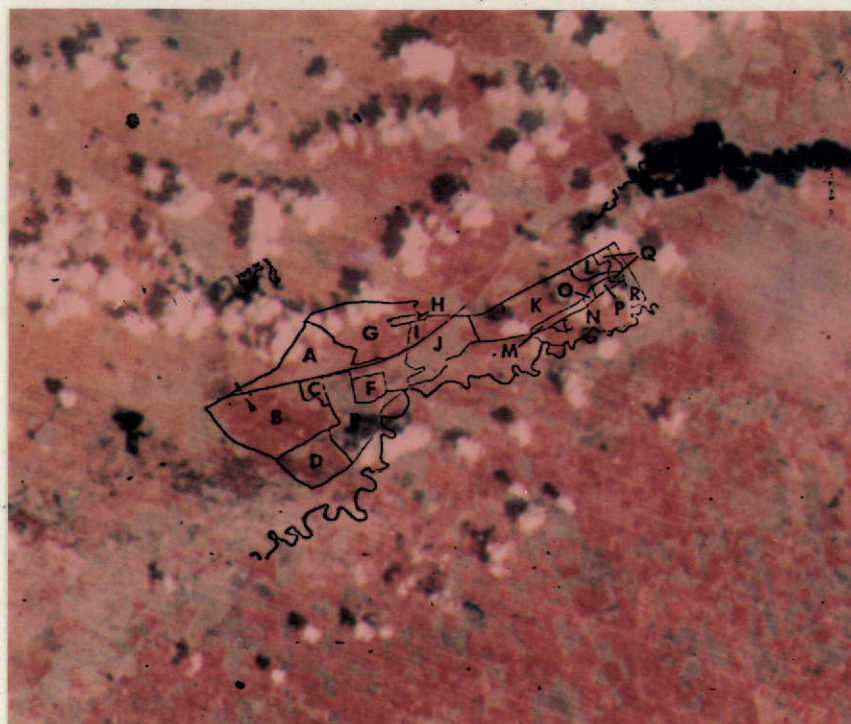


Figure IV-1: THE SHAH MAZRAEH DEVELOPMENT AREA TEST SITE

Crops grown in each field during the 1972 and 1973 season may be found by matching the letter on the image to the corresponding letter below

FIELD	1972	1973
A	PASTURE	PASTURE
B	WHEAT	PASTURE
C	(NO DATA)	BARLEY
D	COTTON	WHEAT
E	COTTON	COTTON
F	BARLEY (IRRIGATED)	BARLEY (IRRIGATED)
G	WHEAT	COTTON
H	(NO DATA)	WHEAT
I	BARLEY	WATER MELONS
J	COTTON	BARLEY (DRYLAND)
K	BARLEY (DRYLAND)	BARLEY (DRYLAND)
L	COTTON	BARLEY (DRYLAND)
M	BARLEY	COTTON
N	PASTURE	COTTON
O	(NO DATA)	SUNFLOWER
P	(NO DATA)	CORN
Q	(NO DATA)	ORCHARD
R	PASTURE	PASTURE



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FIGURE IV-2

A - shows the barley field designated as (J)
in Figure IV-1.

B - is a range area just north of the field
designated as K in the same figure.

vegetation will probably require some form of pattern recognition technique in addition to point-by-point multispectral analysis. Discrimination between these two classes of vegetation is extremely important in order to plan and monitor the balance of land use between agriculture and grazing in this area. Maintenance of this balance is crucial to the success of the range improvement program and therefore to the entire animal protein production program.

The Isfahan Study Area

The second agricultural test site selected for study is the crop region immediately surrounding the City of Isfahan (Figure IV-3), about 400 kilometers south of Tehran. This region, being surrounded by desert, is much drier than the Caspian Sea region to the north. Crops grown there are similar to the Caspian region. Therefore, it will provide a contrasting set of similar crop species that can be used to determine spectral differences on the ERTS images that result from climatic variations. A 1/10,000 scale map was obtained for this area showing the general distribution of crops. Then an overlay was prepared at a scale of 1/500,000 to match ERTS frame Number 1133-06393, 3 December 1972 (Figure IV-3). As can be seen from the illustration, the mapping of the agricultural zone at this point in time can be greatly improved by means of the ERTS-1 image.

As of this date, field checking has not been sufficient in this area to identify actual crops field by field. However, 1/20,000 scale aerial photographs are available for the area which can be used to annotate actual crops during the next field visit. The ground photos of Figure IV-4 are typical of the kind of agriculture and range that surrounds the Isfahan area. It can



C - Cultivated
O - Orchard
A - Arid



Figure IV-3: ISFAHAN AGRICULTURAL TEST AREA



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FIGURE IV-4

A shows a typical grain field in the vicinity of Isfahan while B shows a typical desert range in the same area.

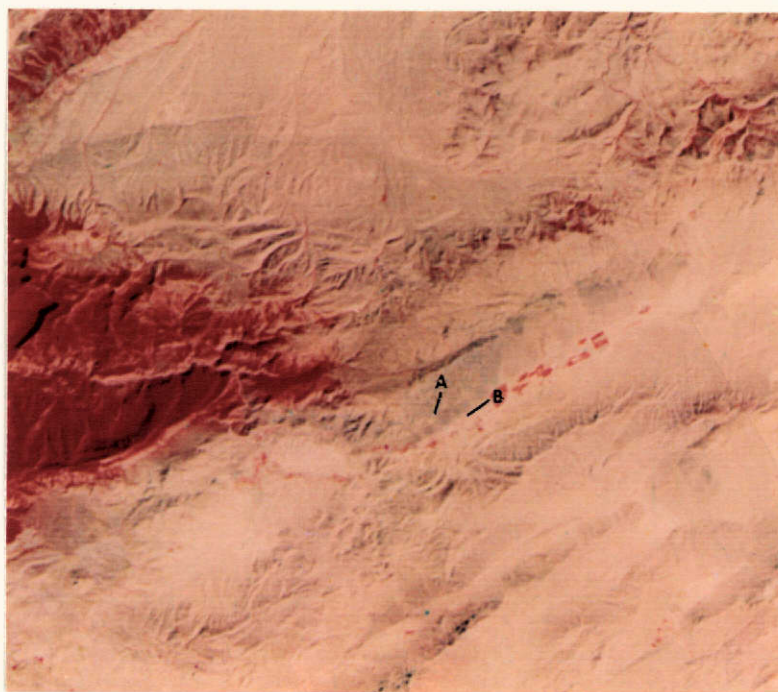
be seen that, in contrast to the Gorgan area, there should be no great problem here in distinguishing between agriculture and range resources from ERTS imagery. Also, there should be no great difficulty in identifying agricultural areas by size and location because of their extreme contrast with the surrounding desert.

On the other hand, discrimination among crop types will be more difficult due to the generally smaller size of individual fields compared to the northern areas around the Caspian Sea. Only a detailed spot-by-spot multispectral analysis combined with cluster analysis by means of the ERTS digital tapes will determine the possibilities for discriminating among crop types in this area. The Isfahan study area and the area around it is much like the cropping pattern in the entire southern portion of Iran. Therefore, reliable techniques for locating and identifying these small scattered agricultural oases are vital to the implementation of ERTS data into the crop survey and monitoring program of the Ministry of Agriculture.

The Golestan Park Rangeland Study Area

The April 1973 trips also resulted in the selection of the Golestan Park area as a rangelands test site (Figure IV-5). This area lies about 75 kilometers east of the southern shore of the Caspian Sea. Here, both protected and unprotected range lands are present in large contiguous areas. The area also encompasses a significant range of elevational differences as well as grass and browse types. It is an ideal area to study the varying signatures of range vegetation on the ERTS imagery.

Large scale maps of the area have been obtained which show the annotated boundaries of Golestan Park. At the time of



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FIGURE IV-5

ERTS frame 1059-06260-7, 20 September 1972
showing the Golestan Park range study area.
(A) indicates the approximate location of
Figure IV-6A showing the higher elevation
range area. (B) indicates the lower elevation
sage area of Figure IV-6B.

writing, it has not been possible to annotate the exact boundaries of the study area on ERTS frame Number 1059-06260, 20 September 1972 (Figure IV-5). This will be done in the near future. A color composite of ERTS frame Number 1221-06270, 1 March 1973 has been obtained which shows some of the study area. Unfortunately, the best rangelands, which are located at high altitudes, were covered with snow. Also, many of the remaining areas are partially obscured by clouds and cannot be intensively studied using ERTS digital tapes.

Figure IV-6 shows two kinds of rangeland characteristics of the Golestan area. The photo on the left (A) shows a portion of the higher elevation range area of superior quality that has been under protection from grazing for several years. The right photo (B) shows a typical sage-type browse area that has also been under protection. The approximate location of the ground photos are indicated on Figure IV-5. One of the low altitude photographic strips used in the multistage range inventory, described later in this report, traversed across the higher elevation range area shown in Figure IV-6A. Therefore, this is an ideal area for more intensive study later in the investigation. The development of techniques to stratify effectively the rangelands of Iran into significant productivity groups will be most important to the animal protein improvement program of the Ministry of Agriculture.

The Neka Zalem Rud Forestry Study Area

The site chosen as the forestry test site is the Neka Zalem Rud Project (Figure IV-7). This project area encompasses approximately 80,000 hectares of which 60,000 hectares are in commercial forest. The Neka project is a long term, experimental forest



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FIGURE IV-6

(A) is an example of the higher elevation,
good quality rangeland in the Golestan Park.
(B) is an example of the lower altitude, poorer
quality sage area.

management and utilization program. It includes the installation of an integrated timber processing facility consisting of a saw-mill and particle board plant as well as various remanufacturing equipment for producing finished products.

The forest management program of the Neka project calls for partitioning the forest into five twenty-year management sections. Harvesting and reforestation activities are to take place in each area so as to obtain a sustained yield of forest products over a one-hundred year period. Within each twenty-year section, forest stands have been identified on aerial photographs and mapped by type classifications. Timber cruises have been completed in the first twenty-year management area so that the species composition and timber volumes are known for each forest type mapped. Copies of these maps and the accompanying data are now being obtained so that the locations of these known stands can be accurately projected into the ERTS images for study.

The study area is shown as the bright red area near the center of Figure IV-7, ERTS Frame Number 1294-06339, 13 May 1973.

Figure IV-8A shows a typical stand of young beech within the Neka forest project.

Figure IV-8B shows a typical grain field that borders the Neka project.

The intermingling of forest, agriculture and range lands is fairly typical of much of the Elburz mountain area. Therefore, the discrimination among them on ERTS imagery is important to the survey and monitoring of these kinds of vegetation resources. While it is obvious that there are color differences discernible in different portions of Figure IV-7, their exact meaning is as yet

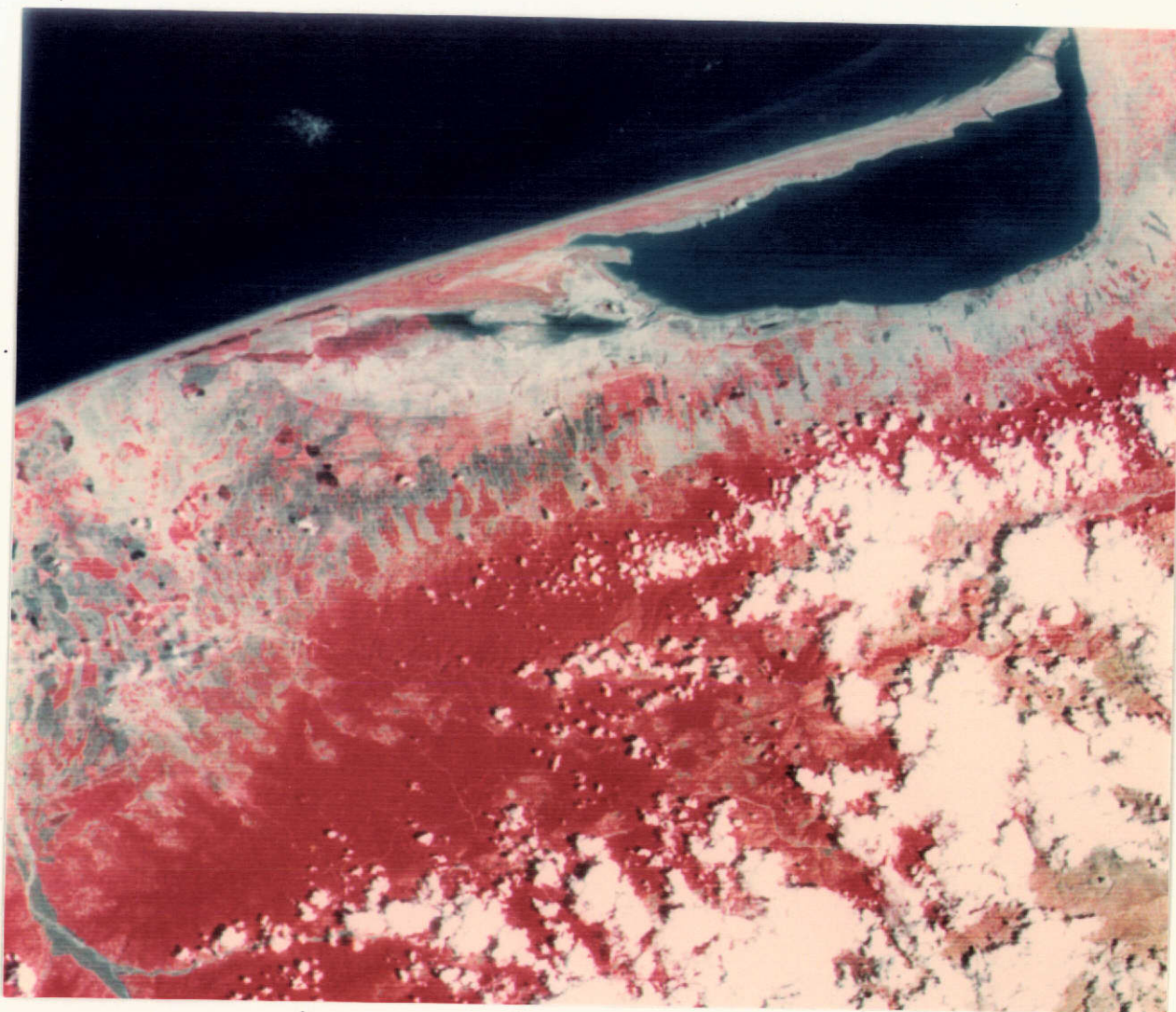


FIGURE IV-7

ERTS Frame 1294-06330, 13 May 1973 showing the southeastern corner of the Caspian Sea and the Neka forest study area. The study area is the bright red area just to the left of the photo center.



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FIGURE IV-8

(A) is a typical young growth beech stand in the Neka forest project area. (B) shows a typical grain field intermingled with the forest and range land in this area.

unknown. A study of the crop calendar of agriculture, and the annual phenologic variations of the major forest and range types will probably be required to discriminate consistently among these three major vegetation groups in this area.

Plans for the Next Reporting Period

During the field trips to the above areas, with ERTS images in hand, it was possible to identify at least the broad differences between agricultural, range and forest areas that are intermingled throughout the region. It was also apparent that finer differentiations on ERTS imagery are possible among agriculture and forest types and that rangeland areas can be categorized as to forage density.

Next, the principal tasks are to quantify the observations in such a way as to permit meaningful experiments to be conducted in multi-spectral analysis over time. The objectives of these experiments would be to:

1. Determine the extent to which major agriculture, range and forest types can be consistently distinguished by means of ERTS-1 data,
2. Determine the extent to which differentiations between species types within each of the three main categories can be made,
3. Determine how well the productive capacity of rangelands can be quantified from ERTS data,
4. Determine the relative efficiency of using ERTS data as an integral part of sampling designs for surveying and monitoring agricultural, range and forest resources, and
5. Determine how accurately timber volumes can be determined from an analysis of ERTS data.

The most likely form of experimentation will be by means of discriminant analysis of the form $Y = X B + e$ in which

Y is the vector of discrete variables relating to classes of vegetation,

X is the matrix of independent variables which describes the vegetation as it appears on the ERTS imagery (i.e. tone, density, color, pattern, etc.),

B is the matrix of coefficients that relate X to Y , and

e is the random error term that is not accounted for by X .

In the short term, manual interpretation techniques will be used to generate the X matrix, while in the long term, the computer compatible digital tapes will be used for this purpose. After determining the coefficients of the training models in the agriculture, forest, and range areas, each test field, forest type, and range condition will be classified by means of the appropriate model. Finally, classification matrices will be prepared showing the performance of the various models. On completion of these experiments, it will be possible to determine the extent to which the ERTS data can be used in a practical way to achieve the objectives set forth above.

The Iranian Range Resources Survey

As mentioned earlier, the Ministry of Agriculture in Iran is engaged in a program to improve animal protein productivity. As part of this program a range resources survey has been initiated to determine

the extent and present condition of the rangelands in Iran and to identify specific areas on which forage improvement programs might be profitably undertaken.

In this range survey, ERTS imagery is being used as a medium for stratifying the population into geobotanical units based on elevation, aspects, and geographical location. Meteorological satellite data are also being employed to plot rainfall and soil moisture patterns, in an effort to interject vegetation growth potential into the range quality evaluation as depicted on ERTS imagery.

The sampling design for the range survey is a stratified three-stage model with variable weights at each stage of the model. The weights are derived from an analysis of each of three scales of imagery. The first stage (primary sample units) of the design consists of ERTS frames. Ten frames are to be selected over the entire country; four in the north around the Caspian Sea and Mashhad areas, and six in the southern part of Iran.

The second stage sample units consist of approximately twelve 1/60,000 scale aerial photographs within each ERTS frame included in the primary sample. On these photos, a more detailed delineation is being made of the lands that are devoted to grazing. As with the data extracted from ERTS imagery, the information extracted from the 1/60,000 scale photos will be used as weights for expanding the data from the third stage to the entire aerial photo.

The third stage of the design consists of sample strips of large scale (1/3,200) 70mm color IR photographs flown across the areas of the 1/60,000 scale aerial photos. Each sample strip is nearly 10 kilometers in length. On these photos, detailed analyses of the range vegetation complexes and densities are being made. Then, a small number of these

areas is visited on the ground where the actual determinations of browse species and tons of forage per hectare are made. These measurements are expanded back through the sampling model to obtain estimates of forage yield for the country.

At this writing, all the data collection has been completed for the four ERTS frames in the northern part of Iran throughout the Elburz Mountains from Tabriz to Mashhad. The three scales of imagery are now being analyzed through which the ground data will be expanded. The final interpretations of the ERTS imagery over the entire area will be done on the color mosaic that is now being prepared for Iran. The data collection for the southern part of Iran will be conducted in early spring of 1974.

SECTION V

ERTS-1 APPLICATION TO IRANIAN MARINE RESOURCES

Introduction

The fishing industry of Iran, in both the Persian Gulf and the Caspian Sea, is an important supplier of protein for the nation and employs several thousand persons. However, it should be noted that the industry is not yet centrally organized, that accurate production figures are not yet available and that modern fishing techniques are gaining acceptance only recently.

Thus, the primary use of remote sensing data (and in particular of ERTS-1 data) in marine resource management in Iran is currently for resource measurement and inventory rather than for influencing resource management. To date, interpretive efforts of ERTS-1 data have been concentrated on analysis of sedimentation and wetland areas in the Iran coastal zone, and on the identification and measurement of coastal nursery areas. The studies began in April of 1973 and the results reported here are, thus, of a preliminary and limited nature.

Marine Analysis

In the Fourth Plan for the development of Iran, a fisheries project was proposed for the Bushehr area of the Persian Gulf. An examination of the ERTS-1 imagery of this region was, therefore, appropriate. The imagery shows that there is, in fact, an extensive coastal wetlands nursery area here, that the coastal waters are highly laden with sediment and the fisheries development potential is substantial. More important, however, is the fact that the ERTS-1 imagery also reveals the existence of a much larger nursery area off the island of Qeshm, southwest of Bandar Abbas. Here the ERTS-1 imagery indicates that there are about 5500 hectares of wetlands, and that highly sedimented

areas cover some 350,000 hectares and extend more than 100 kilometers along the coast.

Figure V-1 shows the extent of the areas involved, and was produced by outlining the coastal wetland area using MSS band 7 imagery, and overlaying the resultant wetland delineation on an MSS band 4 image.

Similarly, the ERTS-1 imagery reveals substantial nurseries and sediment areas at the head of the Persian Gulf. This is a deltaic area fed by the Arvand-Rud (the lower course of the combined Tigris and Euphrates), together with the much smaller Karun and Jarrahi Rivers. Together, these systems bring down large quantities of silt and, thus, are extending the land steadily seaward. A zone of swamps, 64 kilometers wide, is present in this region and provides a very large fisheries nursery. Using the ERTS-1 imagery, the extent of the nursery area is readily defined as is the course and extent of the sediment. The area of the marshy land is estimated from ERTS-1 imagery to be 430,000 hectares, and this is delineated on Figure V-2. It will be noted that on this image the sedimented areas exceed the area of clear water. Since the yield of coastal fisheries has been found in many parts of the world to be highly correlated with the ability of the fishing fleet to locate itself at the boundary of the sedimented/unsedimented area, these boundary delineations using ERTS-1 imagery have high potential value.

For the analysis of sediment and turbidity, it was found that the use of the separate black and white bands is much preferable to examination of color composites. The latter, because of the very strong infrared absorption, fail to show the structure of the sedimented and turbid areas. Using single band products, one can easily determine the extent of the sediment plumes.



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FIGURE V-1 COASTAL WETLANDS AND SEDIMENT
 CURRENTS SOUTHWEST OF BANDAR ABBAS

This image indicates approximately 5500 hectares
 of wetlands (shown in blue)

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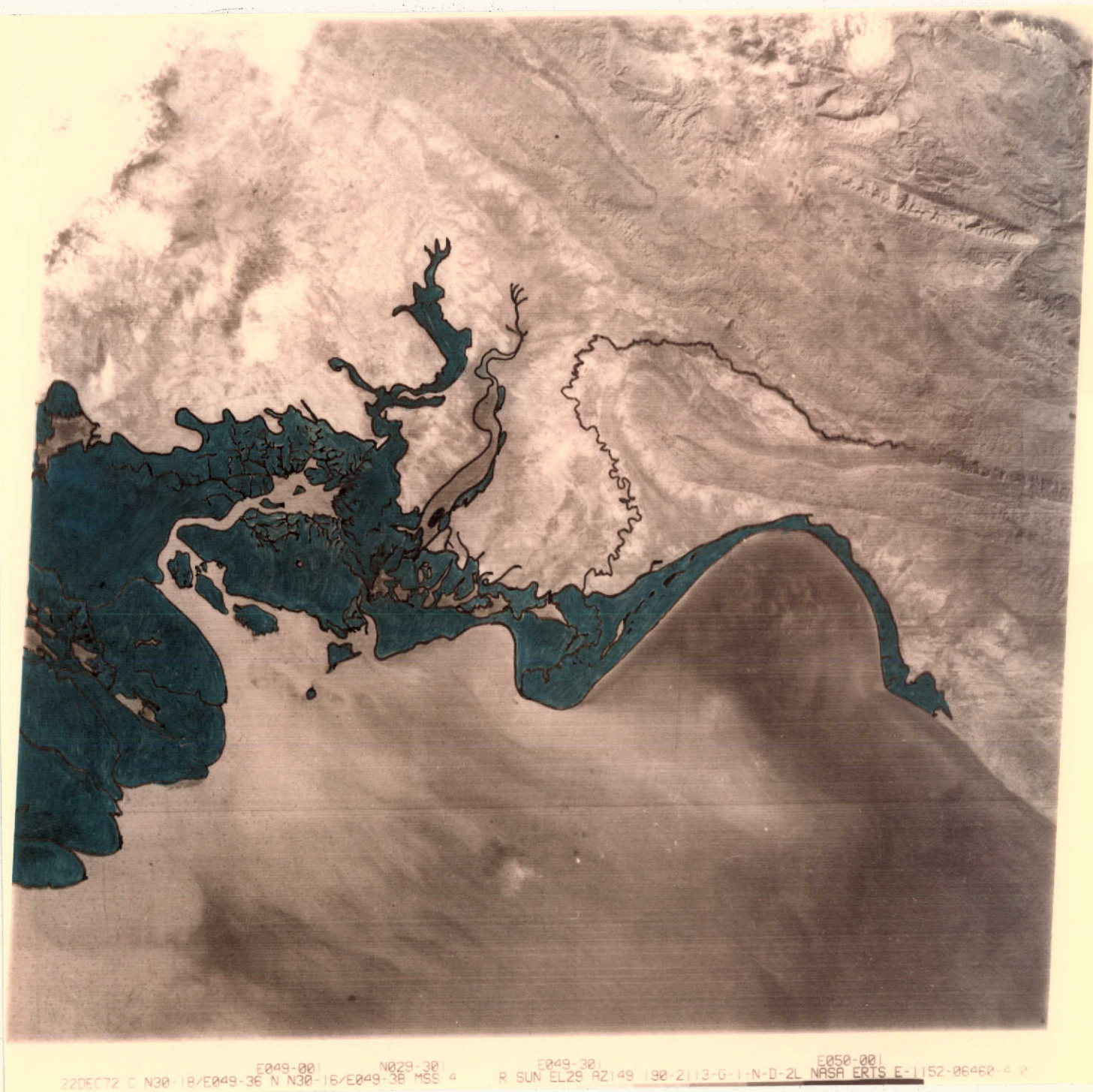


FIGURE V-2 MARSHLANDS IN THE ARVAND-RUD

Preliminary examination indicates that there are 4.3×10^5 hectares of marshlands in this area at the head of the Persian Gulf. Marshlands are indicated in blue.



ERTS-1 data also reveals the direction of some of the off-shore currents, which will also be of major importance in future fisheries planning. Figure V-3 shows some of these currents, flowing southeastward into the Oman Sea. Much work remains to be done in this area.

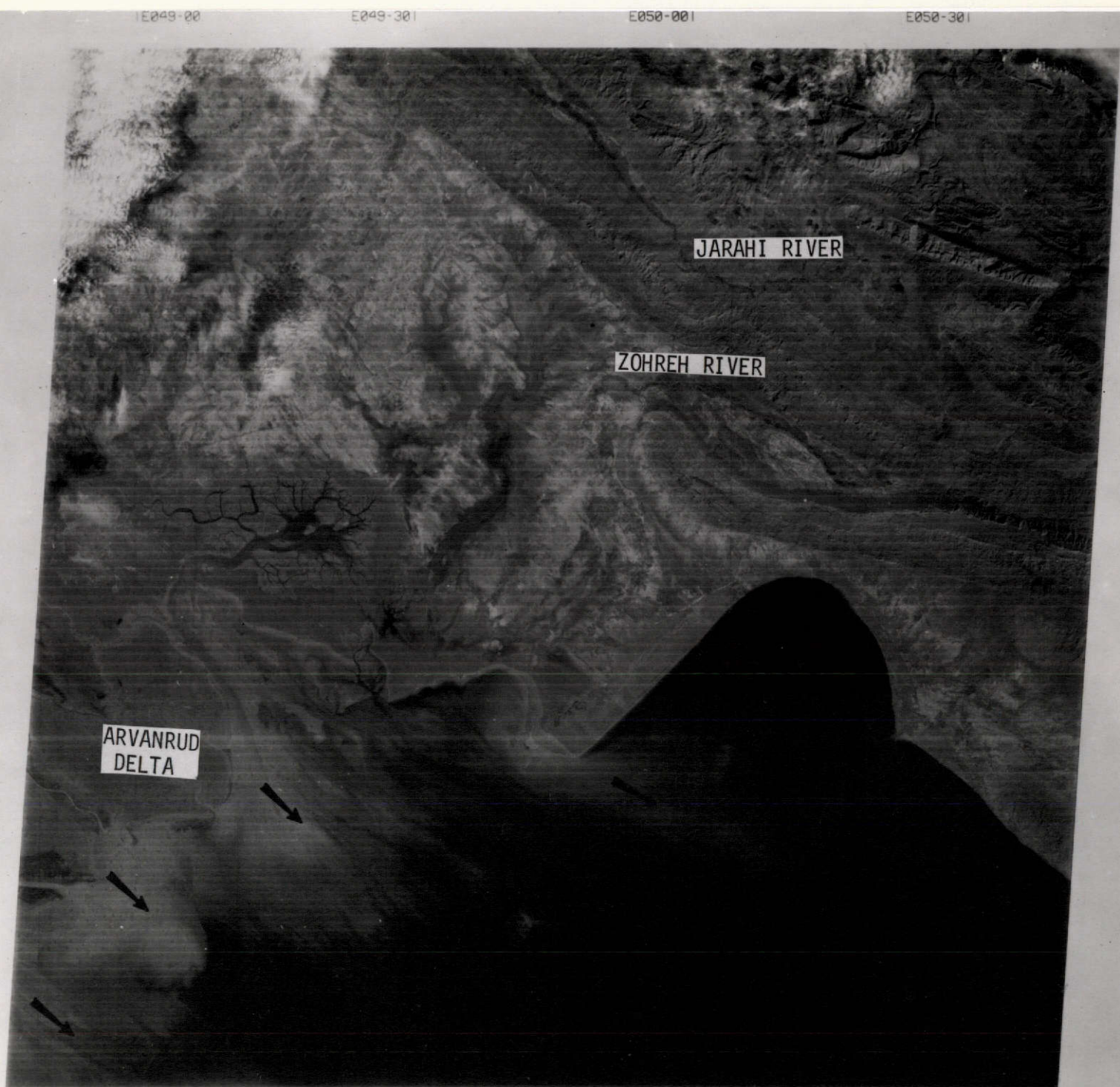
Planned Activities for the Next Reporting Period

The Persian Gulf nursery areas and wetlands identified and delineated on the ERTS-1 imagery will be studied using repeated ERTS-1 coverage, to provide an idea of their seasonal fluctuations and to assess as accurately as possible the movement and behavior of the sedimented/clear water interface.

In addition, imagery of the south shore of the Caspian will be analyzed. There is evidence from a first comparison of ERTS-1 images with aerial photographs taken in 1955 that the shape of the shoreline in the Gorgan Bay is changing significantly. The barrier bar seems to be increasing eastward toward the mainland, which might lead to eventual obstruction of the bay entrance. This analysis will, therefore, be of great practical interest and constitutes an important action for the next reporting period.

Conclusions

A first analysis of the application of ERTS-1 data to Iranian marine resources shows that the imagery permits the identification of many features important to fisheries development. In view of the non-centralized nature of the Iran fishing industry, the knowledge gained using ERTS-1 imagery will be used in general national planning rather than in current fishing operations. However, for the same reason, the remotely sensed data offer information that cannot now be provided by the fishing industry itself, and is an important variable that cannot be obtained in other ways.



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FIGURE V-3 NORTH WESTERN PART OF THE PERSIAN GULF

Indications of current directions are clearly seen
in this image and marked by arrows.

0 — 10 km
scale

SECTION VI

EXPERIMENTS IN URBAN LAND-USE ANALYSIS USING ERTS-1 DIGITAL TAPES

Introduction

In April, 1973, having performed a considerable amount of analysis using the 70 mm and 9"x9" NASA film products, the Government of Iran began to investigate the potential of the computer compatible digital tapes. The motivation for this investigation was two-fold: first, conversations with other active investigators had suggested that the dynamic range of radiometric intensity present on the digital tapes exceeded that of any of the image format film products; and second, a number of applications relevant to Iranian needs call for the rapid assessment of area and for the differentiation of types of ground cover. Reports from workers using digital methods (Sheffield, 1972) had shown that area estimation and ground cover analysis could be performed using computer processing of the ERTS-1 tapes to good effect.

Investigations to date have been confined to the analysis of tapes of an area surrounding Tehran (See Figure VI-1).

Digital Processing

Following a digital expansion of the computer stored image of the Tehran image shown in Figure VI-1 and output to a film recording device, it was possible using bands 5 and 7 of the MSS Imagery to see clear evidence of road networks in and around Tehran. Using this image, taken on 5 October, 1972, the Plan Organization set out to apply a sequence of Digital Image Processing techniques, with the specific objective of sharpening the road nets visible in the image, and of providing a first analysis of land use within the urban area of Tehran. The choice of bands 5 and 7 reflected experience

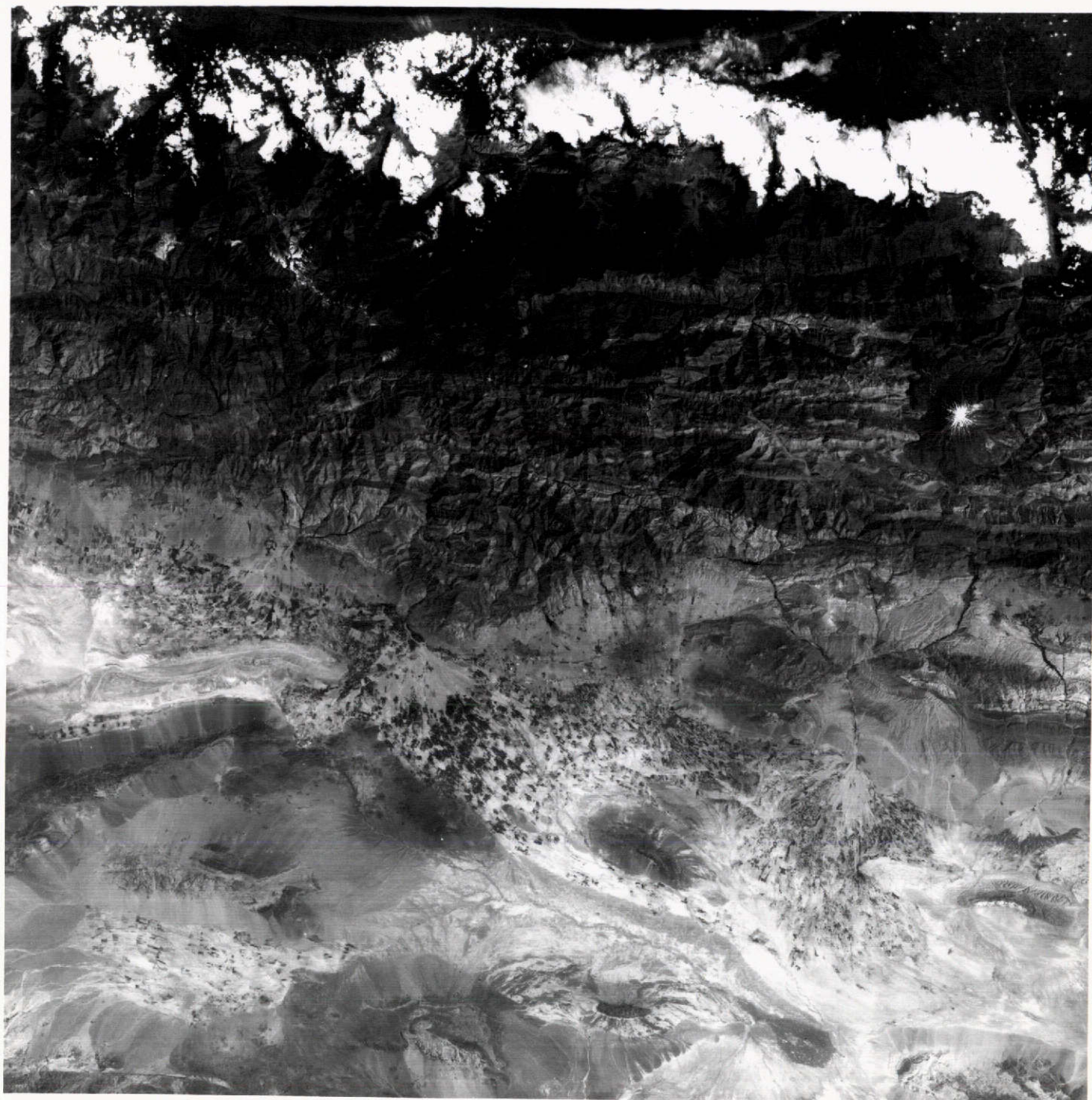


FIGURE VI-1

Tehran frame from ERTS-1 digital
tapes, Band 5



derived in work using the 70 mm and nine-inch film products, which suggested these bands should show most clearly the road networks.

The sequence of digital operations performed on the tapes was as follows:

1. reformat ERTS tapes of Northern Iran to separate spectral bands
2. gray scale adjust band 5 (red) to linearly stretch the gray level values from 5 to 95 into the range 0 to 255.
3. Output the adjusted picture to a Litton Image Recorder. A 1536x1536 window was initially displayed. This was used to determine the location of a 512x512 window showing the city of Tehran and environs.
4. The unadjusted original image was windowed to separate out the appropriate 512x512 region and this region was subjected to the Laplacian operation. This operation computes at each point an isotropic derivative and consequently designates the location of edges in the scene.
5. This Laplacian image was gray scale adjusted to give gray levels in the range 0 to 255.
6. The adjusted Laplacian and the original image were added together.
7. The adjusted Laplacian was added to the result of step (6)
8. The result of step (7) was gray scale adjusted to fill the range 0 to 255.
9. The result of step (8) was output to the Litton Recorder
10. The segment of the image produced in step (9) that exhibits the city of Tehran itself was photographically enlarged and printed on high contrast paper.

The addition of the Laplacian to the original image is an edge enhancement operation that sacrifices radiometric fidelity for sharpness or crispness of lines and edges. Similar operations were performed on Band 7 (second IR band). The final product, created as the end product of the above sequence, is displayed in Figures VI-2 and VI-3.

The images of Figures VI-2 and VI-3 were compared with a standard commercial highway and urban feature map of Tehran. A Bausch and Lomb zoom transfer scope was used to overlay the map and the image. The device permits rotation, translation and differential scale change of the two, so that a very accurate overlay was possible.

It is apparent that the ERTS-1 image revealed urban developments that had occurred since the production of the map (dated 1970, but probably containing a good deal of information that had not been updated since 1968). In particular, major new building developments were readily identified.

The city can be partitioned into several land-use categories simply by delineating between basic tone and texture groups on the image. For example, the central business district of Tehran is imaged as a region of scattered black picture elements on a dark gray background. It is noticeable that the road network is less discernible in the central part of the city than it is in the older sections, and that at the scale displayed here single major buildings produce definite recognizable effects on the image tone.

It is clear that even with a ground resolution of only 70 meters, ERTS-1 offers a tool under good cloud-free conditions by which urban developments in major cities can be easily and cheaply identified, at least to a first level of accuracy.



FIGURE VI-2

City of Tehran from ERTS-1 digital
tapes, Band 5



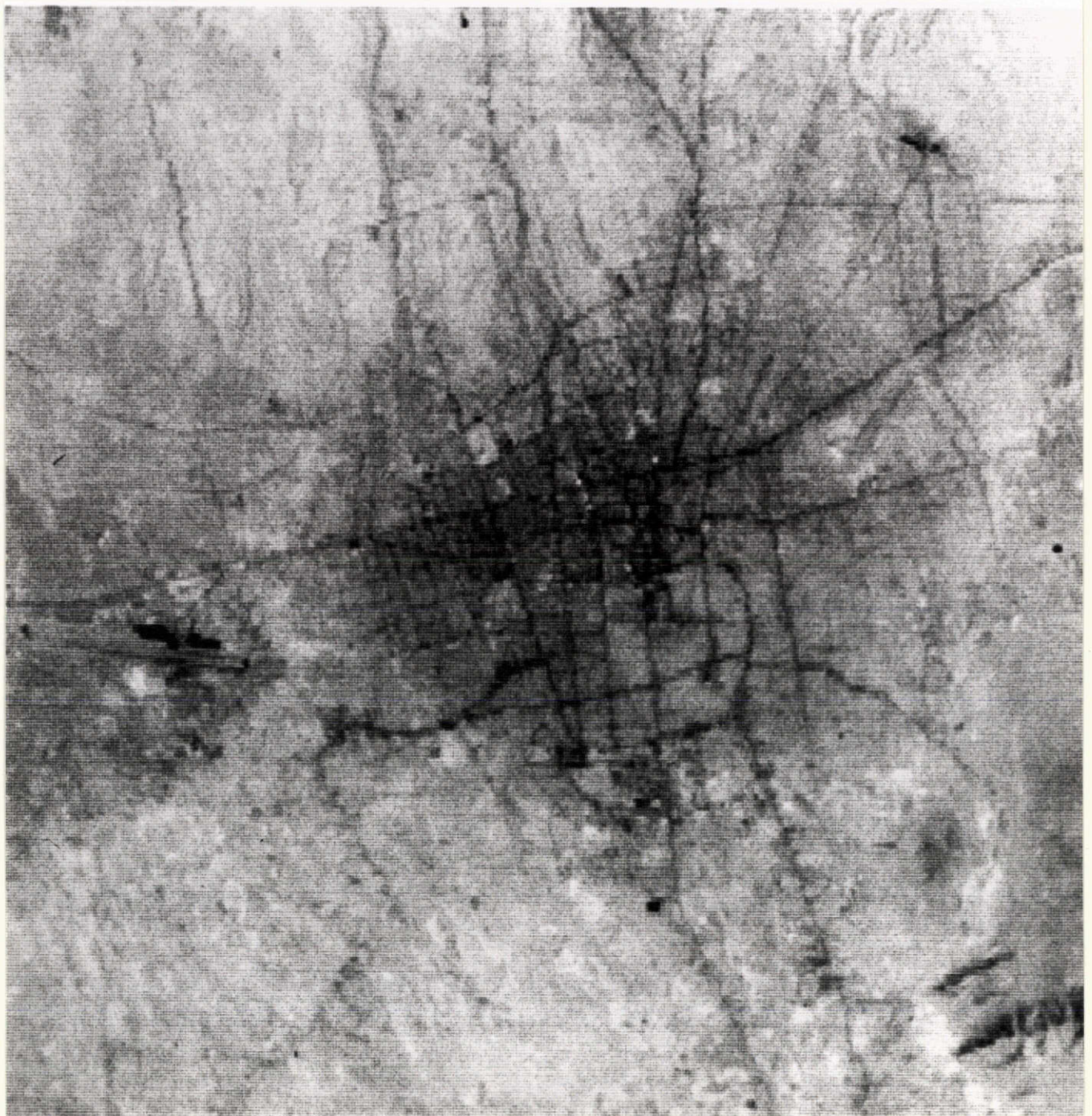


FIGURE VI-3
City of Tehran from ERTS-1 digital
tapes, Band 7



Plans for Continuing Work Using Digital Tapes

The work of the Plan Organization using the ERTS-1 digital tapes is still at an early stage. In the next reporting period, it is proposed to evaluate images of the same area in bands 4 and 6, to determine their potential for land-use analysis similar to that now being conducted using bands 5 and 7.

It is also proposed to perform experiments in the area of multi-spectral analysis using classification programs that have been developed for crop classification in the United States. The Plan Organization is currently investigating the availability of the LARSYS programs, developed by Purdue University, for use on the 370/145 computer located at the Plan Organization in Tehran. Additional analytical programs and output recording devices are also under consideration.

Conclusions

Although the experiments to date using the digital tapes have been very limited, it seems clear already that they represent an information source of considerable promise. The first results obtained suggest that their radiometric range and ground resolution are superior to that of the film products. It therefore seems logical to perform a considerable amount of digital analysis on the ERTS-1 tapes, before moving to image production. The Plan Organization of Iran looks forward to a continuing series of experiments utilizing ERTS-1 digital tapes, in applications to agriculture and forestry (using multispectral analysis), to hydrology and turbidity analysis (using intensity adjustments and area computation), geological analysis and urban land-use analysis (using enhancement

techniques) and to snow cover mapping (using a gray level slicing and area computation). Each of these applications should benefit from an appropriate use of the computer-compatible tapes provided by ERTS-1.

SECTION VII

ERTS FALSE COLOR INFRARED MOSAIC OF IRAN

Introduction

Upon seeing the first examples of false color infrared composite images of Iran, it was at once apparent that these images had great value and had application to a wide variety of disciplines. Consequently, the Government of Iran requested Earth Satellite Corporation of Washington, D. C., to undertake production of a color matched mosaic of all Iran, using ERTS-1 imagery at a scale of 1:1,000,000 for the entire country. The mosaic is being produced in five sheets. A reduced copy of the first sheet is included as Figure VII-1. This segment of the mosaic consists of twenty-five images. Three sheets are completed and the remaining sheets are soon to be completed. To our knowledge this type of color matching has not been successfully attempted elsewhere.

Applications

The existing color mosaic sheet has already been used as a basis for reconnaissance level tectonic mapping and for planning and conducting a range inventory in conjunction with an animal protein production project. We anticipate that the mosaic will serve as a basis for a wide variety of inventory and planning functions in the future including intermediate level tectonic and geologic mapping, mineral and petroleum exploration, forest inventory, hydrologic mapping, drainage basin analysis, location of geologic hazards, land use inventory and planning, integrated regional development planning, and ground water inventory and exploration.

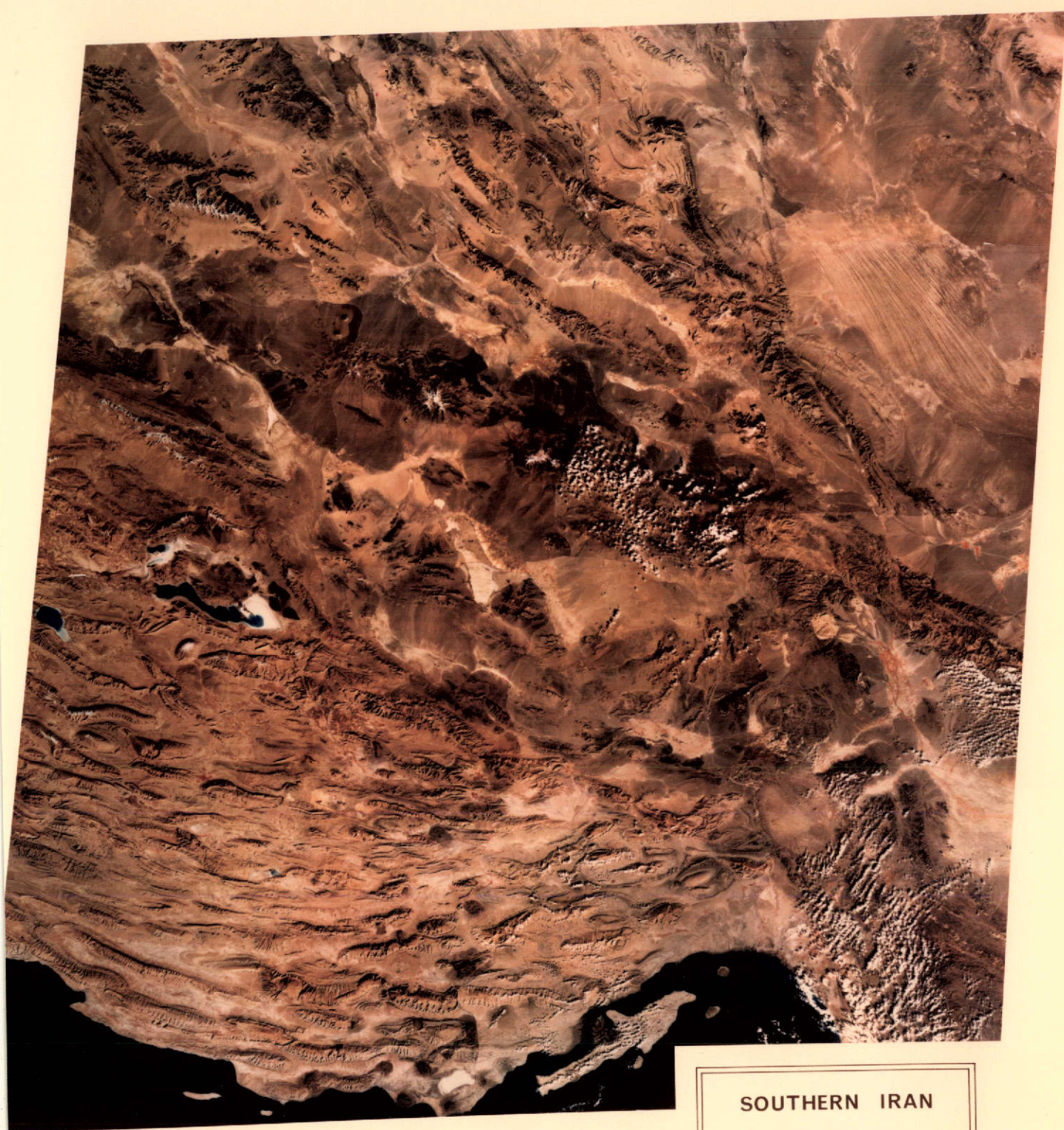


FIGURE VII-1 ERTS COLOR MOSAIC OF IRAN

This is a reduced copy of the first sheet of a mosaic of Iran composed of color infrared color composited (bands 4, 5 and 7) ERTS-1 images. The mosaic of the entire country will consist of 5 sheets at a scale of 1:1,000,000. This copy has a scale of approximately 1:3,360,000. The entire mosaic will be completed in the near future.



Cartographic Characteristics

At this point it is worth discussing some of the "cartographic" characteristics of the mosaic. Photogrammetrically this is an uncontrolled mosaic, but it is much more accurate for its scale than any controlled aerial photography mosaic in x-y errors, primarily due to the absence of x-y errors caused by tilts in the camera and to excellent dimensional stability of the film and digital data.

Errors of a single frame 1:1,000,000 are not increased by reproduction, as first generation and fourth generation positives have essentially identical geometrical errors (based on monocomparator work by Colvocoresses of the U. S. Geological Survey).

The largest error is in scale, although this is relatively removed if all 70 mm images are enlarged at the same time with the same enlarger settings. However, the achievement of exactly 1:1,000,000 scale is very difficult because of the problem of precisely identifying geodetic control points. We can probably achieve two parts in 10,000 (0.2 mm across) scale accuracy. Thus, the scale from mosaic sheet to mosaic sheet may vary from 1:1,000,200 to 1:999,800.

Using least squares solutions of a best fit to ground control, it appears that a standard error of ± 300 meters is usually achieved for bulk MSS imagery. There is a variation of the error from ± 225 meters to ± 400 meters in imagery of different dates with early (July 1972) imagery being geometrically less accurate. This means that at 1:1,000,000 routine accuracy of ± 0.3 mm per frame can be achieved.

Enough for a single frame, but how accurate is a sheet of twenty frames? Little has been done (from a written literature search) on errors of mosaics because standard photo mosaics have high errors due

to the inaccuracies inherent in the original geometry of the entire system. It appears that standard error propagation in a mosaic of ERTS images would be a random walk system along a line from point to point. If so, the error is about ± 0.45 mm for lines across 4 to 6 frames. This is consistent with the mosaics we have observed. However, it probably reaches a plateau at 7-10 images after which the rate of error accumulation decreases because of the correlating effects of the frames on either side, which inhibit error propagation above certain visible limits. Thus the error over many frames would approach an asymptote of perhaps ± 0.7 mm.

This means that a 1,000,000 scale ERTS photomap may meet National Map Accuracy Standards. In future work efforts will be made to identify established geopoints (geodetic ground control points) on the imagery in order to determine or confirm the geometric fidelity of such uncontrolled mosaics and investigate the feasibility and value of compiling ERTS mosaics with control. Iran has a geodetic network (triangulation and radio triangulation) and is currently establishing a series of positions utilizing the Doppler georeceiver and active navigation satellites.

SECTION VIII

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